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(54) Plate stack heat exchanger

(57) A heat exchanger comprises a matrix of stacked superposed plates 1, 2 which enclose separate ducts 3 4 for two fluids involved in heat exchange. Openings 5 in complementary shaped portions 13, 14, form feed pipes and discharge pipes 7, 7' each connected to one group of ducts in the matrix. The feed pipes and discharge pipes are made up of a column of rings 8, 9 clamped axially in a sealing-tight manner between the shaped portions which rings, in various spaced-apart planes, form a fluid connection 10 with one group of ducts 4 or a fluid barrier against the other group of ducts 3 in the matrix.

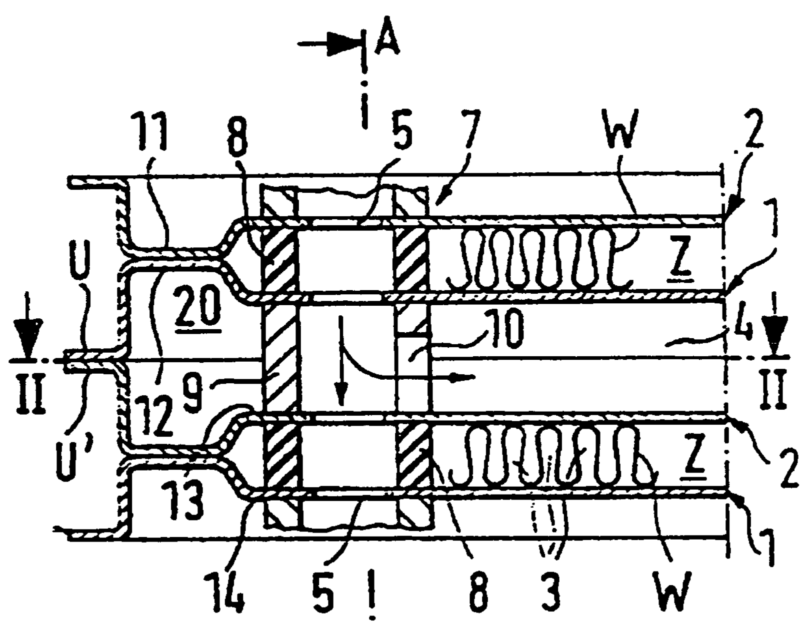

FIG. 3

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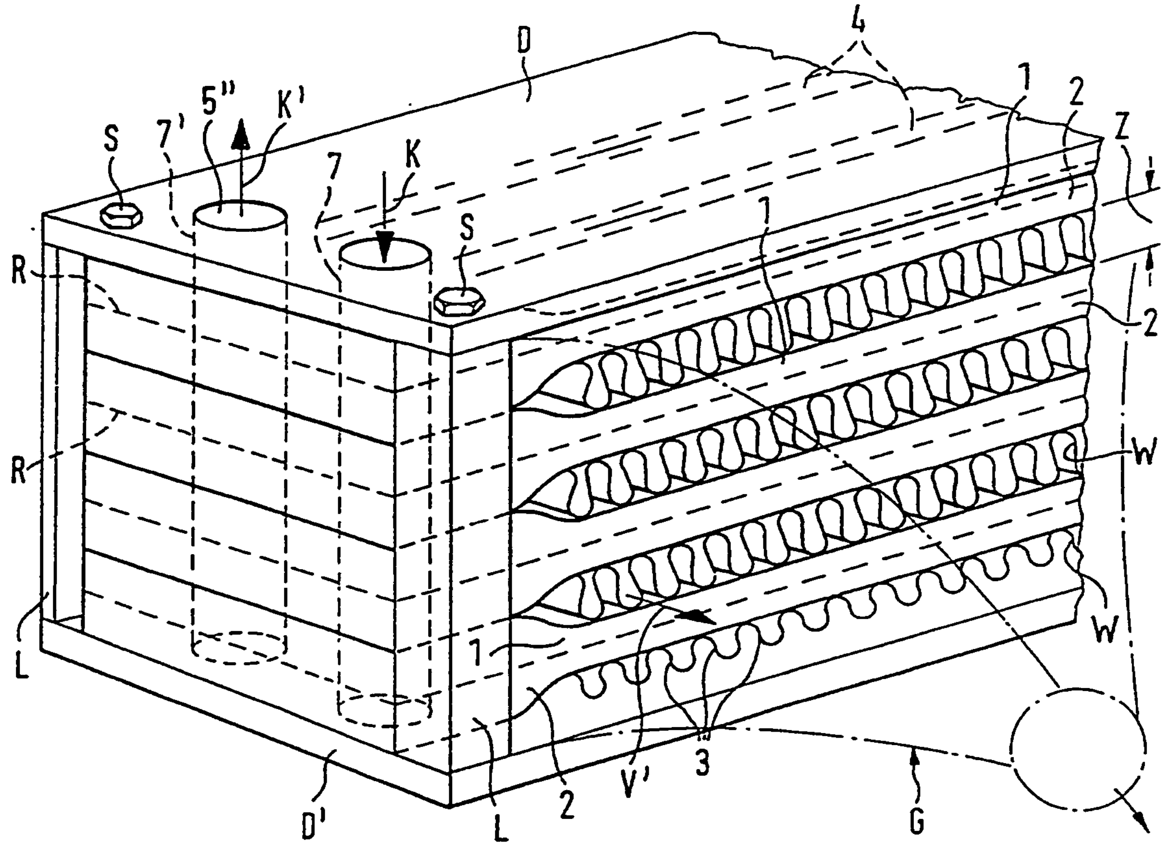


FIG.1

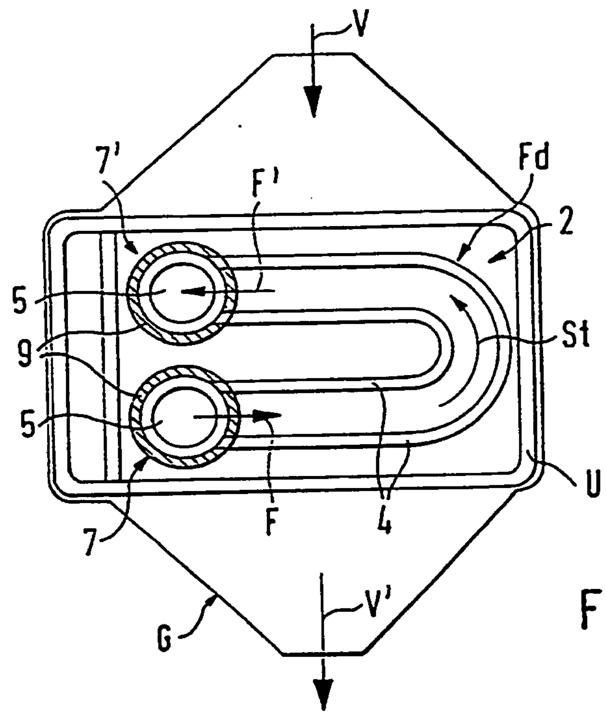


FIG.2

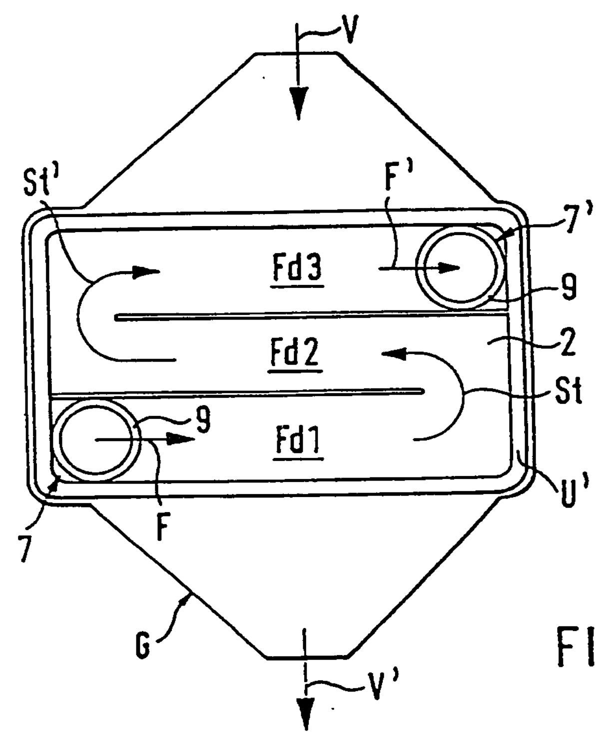


FIG.2a

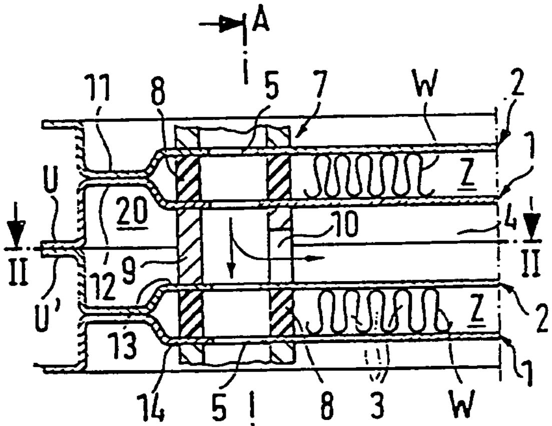


FIG. 3

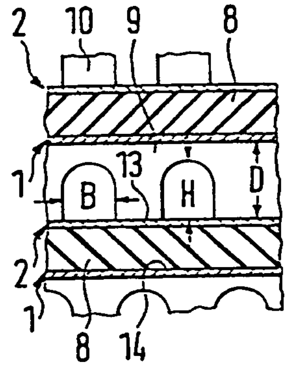


FIG. 4

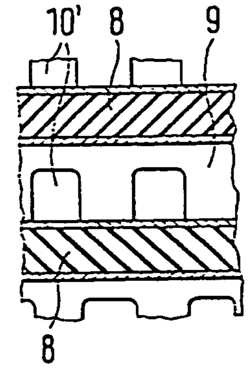


FIG. 5

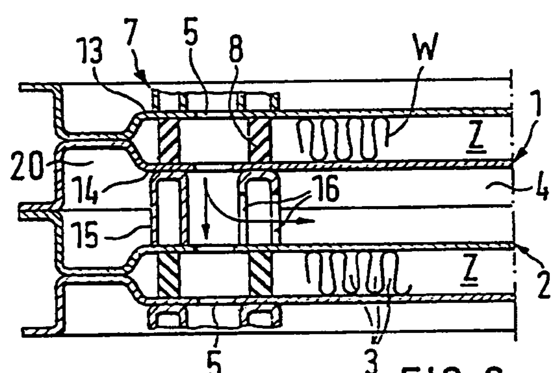


FIG. 6

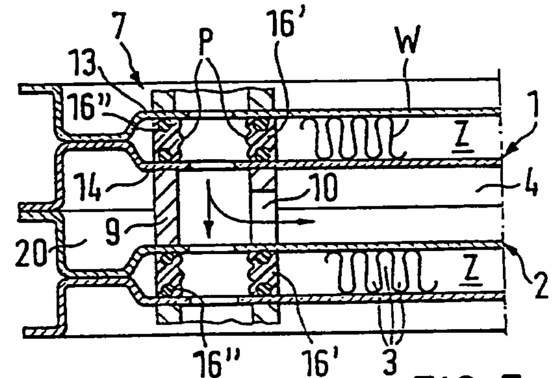


FIG. 7

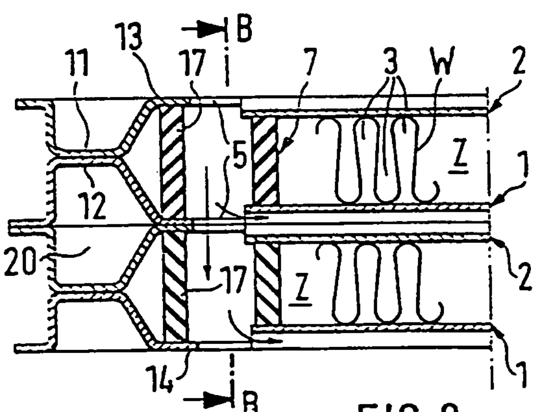


FIG. 8

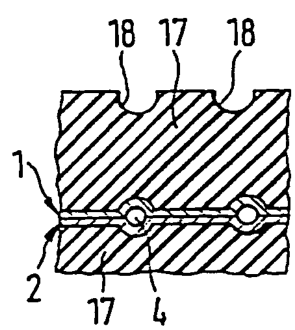


FIG. 9

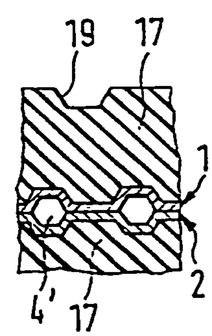
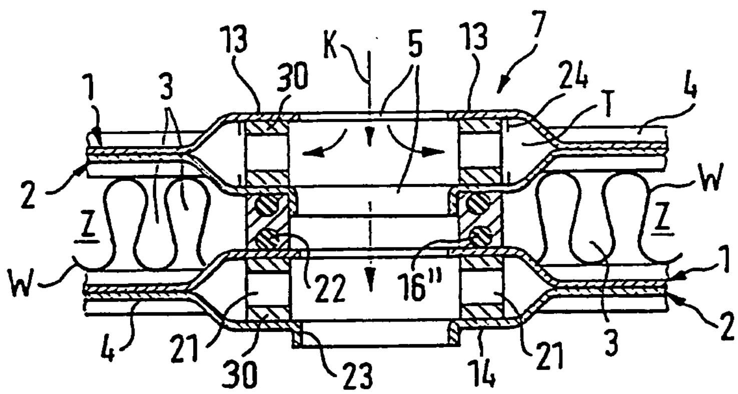


FIG. 10

FIG.11


13
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13
7
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30
24
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16"
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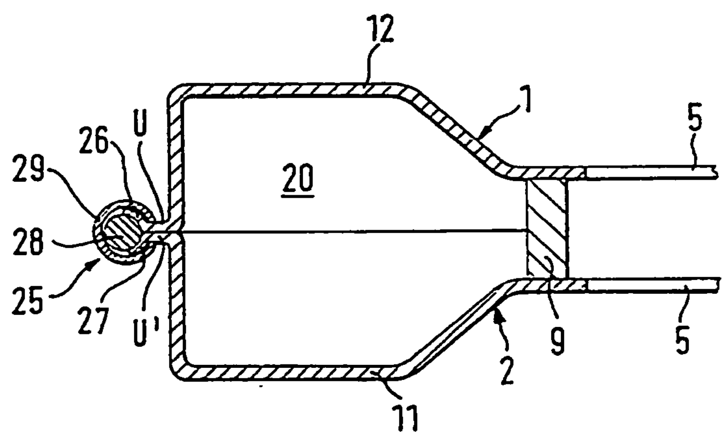
FIG.12


12
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5
U
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29
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27
U'
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11

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A HEAT EXCHANGER

The invention relates to a heat exchanger particularly for use as a charge cooler for an internal combustion engine and formed of a stack of plates defining two sets of channels, one for each of the heat-exchange fluids. Such a heat exchanger is the subject of US-PS 4 592 414. In this heat exchanger, feed and/or discharge or distributing pipes are disposed in pairs side by side at each end of the stack of plates. The plates are spaced apart in the longitudinal direction of the feed or discharge pipes mainly by locally dished or bulging plate portions enclosing respective bulges in each complementary fitted-together pair of plates; these bulges, when the pairs of plates are superposed, form the feed and discharge pipes and communicate via openings in the bulging plate portions, local pipe connections being provided by alternate engagement of flanges in associated openings on the plate portions resting on one another; for the purpose of local separation into a feed pipe and a discharge pipe, completely separable bulges in a pair of plates can be formed by lug-like embossed plate portions.

Each pair of plates includes one or two ducts for single-pass or double-pass flow of the heat-absorbing fluid, depending on the arrangement of the plates, the ends of these ducts each merging into the spatially widened bulges in a feed or discharge pipe; each pair of plates is surrounded or supported against one another along common outer edge regions similar to flanges or strips.

The known case requires complicated, expensive moulding or embossing of the plates, which themselves need relatively thick walls in order to obtain a mechanically stable, self-supporting structure. The

thick-walled plates have inter alia the following disadvantages: non-optimum heat exchange (reduced heat transfer per unit time); relatively large amount of material required, and relatively great weight. Since in the known case all the plates are welded or soldered together, "module replacement" or "modular" addition to the heat exchanger in accordance with variable power and work cycles of internal combustion engines, independently of the supplier or heat-exchanger manufacturer, is practically impossible. A "module" refers to a pair of plates which in US 4592414 are fastened together to form hollow units.

The object of the invention is to design a heat exchanger which is comparatively inexpensive as regards manufacture and materials (inexpensive embossing and thin plates), is relatively light-weight and provides a very simple means of constructing feed and discharge ducts which can cope with temperature or mechanical stresses and are sealed in an optimal manner.

According to the invention there is provided a heat exchanger comprising a matrix of stacked superposed plates which enclose separate ducts for two fluids involved in heat exchange and have complementary shaped portions with openings for the formation of feed pipes and discharge pipes respectively connected to one group of ducts, in which the feed pipes and discharge pipes are each further made up of rings arranged along the axis of the respective pipe and clamped in a sealing-tight manner between the shaped portions, these rings in their various axially spaced planes forming a fluid connection with one group of ducts and/or a fluid barrier against the other group of ducts in the matrix.

The invention is also directed to a modular element for such a heat exchanger, formed by a pair of plates and corresponding ring or rings.

The invention provides a mechanically stable plate

structure, more particularly in the region of the feed or discharge pipes, the rings used being basically supporting, spacing and sealing means between the plates, which are clamped to one another by suitable clamping means in the longitudinal direction of the feed or discharge pipes. Optionally, individual rings can be made of an elastomeric material, either entirely or partly or at least at the ends for contacting the plates; these rings are preferably disposed between those complementary bulging plate portions at which the heat-absorbing fluid, e.g. cooling water, has to be shielded in a sealing-tight manner against the duct structures in the matrix which convey the heat-dissipating fluid, e.g. compressed hot air, and which optionally are also sealed against the surroundings of the plate heat exchanger (the corner region of the plate matrix).

Preferably, within the scope of the invention, external sealing welding is provided along the edge for those shell-like complementary pairs of plates which form or enclose duct structures for the heat-absorbing cooling agent and which enclose the rings or distributing structures at the same side as the rings, in order to guide the heat-absorbing fluid as if in a pipe and to distribute it uniformly in a controlled manner. These welded pairs of plates are interchangeable or optionally replaceable modules of the heat exchanger. These plate modules can be clamped together or additionally abut one another at facing plate portions which are flattened opposite the bulging portions for the rings. Bead-like positively corresponding plate centring means can be provided at the locally flattened contact places, or alternatively a spot-welded or hard-solder connection can be provided at the aforementioned contacting places.

The previously-discussed construction enables

fully welded modules to be stacked on one another, and the pipes can be manufactured simply by inserting sealing and/or spacing rings between two such modules. The rings for anchoring between the respective plates for the feed pipes or discharge pipes in the matrix can be centred and held in position in very simple manner, e.g. by bead-like recesses on the plate portions or by projections, knobs, annular beads or flanges, the flanges optionally engaging like a collar in a ring.

For a better understanding of the invention embodiments will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a general perspective diagram of a heat exchanger in accordance with the invention;

Fig. 2 shows a section on II-II through Fig. 3;

Fig. 2a shows a variant viewed along II-II in Fig. 3;

Fig. 3 is a longitudinal section of a half of the plate matrix of Fig. 1;

Fig. 4 is a view in developed projection in the plane of the drawing along A-A in Fig. 3;

Fig. 5 is a view corresponding to Fig. 4 of another variant;

Fig. 6 is a view corresponding to Fig. 3 of a second embodiment of the invention;

Fig. 7 shows a third embodiment;

Fig. 8 shows a fourth embodiment;

Fig. 9 is a view in developed projection in the plane of the drawing along B-B in Fig. 8;

Fig. 10 is an alternative to Fig. 9, viewed along B-B of Fig. 8;

Fig. 11 is a view in longitudinal section of a fifth embodiment; and

Fig. 12 is a longitudinal section illustrating an alternative plate-connecting means.

In Fig. 1 the heat exchanger is in the form of a

plate charge cooler, the plates being clamped between outer closure covers and an outlet-end casing contour for the cooled fluid (compressed air) flowing out of the matrix. The superposed stacked plates 1, 2 are clamped to one another between an upper and a lower closing cover D, D', with interposition of supporting bars L, preferably along the front and rear end regions. Clamping can be by bolts, which have screw heads S. Feed pipes and discharge pipes 7, 7' formed between the plates 1, 2 are associated with openings 5', 5'' in the top cover D. Heat-absorbing fluid, e.g. cooling water is supplied through one opening 5' in the direction of arrow K and flows through the feed pipe 7 into one group of ducts 4, each duct being anchored in a pair of plates 1, 2. At the downstream side, the group of ducts 4 adjoins the discharge pipe 7', from which cooling water flows out of the opening 5'' in the direction of arrow K', the water being heated as a result of heat exchange with the supplied heat-dissipating fluid, more particularly hot compressor or charging air V (see Fig. 2). Along the outer peripheral lines R in Fig. 1, the pairs of plates 1, 2 can be welded together in sealing-tight manner to flange-like complementary edges U or U' (see also Figs. 3, 6, 7, 8); preferably a jet or roll-seam weld can be used, or temperature-resistant hard solder can be used.

The plates 1, 2 can be made e.g. of steel, copper or aluminium sheets. Between them, they form cavities Z, in which additional ducts 3 extending transversely to the first group of ducts 4 are formed by corrugated sheet-metal inserts W, for conveying the heat-dissipating fluid, more particularly hot charging air V, which flows out of the matrix along V' (see Fig. 2) at an appreciably reduced temperature, and is supplied as charging air through an opening in the casing G of the respective internal combustion engine.

Fig. 2 is to be understood in accordance with section II-II of Fig. 3 and shows a plate in the matrix, diagrammatically indicating a complementary reverse-flow pipe matrix formed between a pair of plates and connected to respective openings in the feed pipe or discharge pipe. The groups of ducts 4 are guided so that the direction of flow reverses (arrow ST) so as to co-operate with the stated direction of flow V, V' of the heat-dissipating fluid, i.e. hot charging air through the respective other ducts 3, to form a cross-counterflow heat exchanger. To this end a U-shaped plate tube matrix projecting transversely relative to the feed pipe and discharge pipe 7, 7 is formed over the area Fd (Fig. 2) of the group of ducts 4 formed from complementary recesses between a pair of plates 1, 2; the matrix is connected to the feed pipe 7 (Fig. 2) on the inflow side (arrow F) and to the discharge pipe 7' on the outflow side (arrow F').

Fig. 2a embodies a design of the plate heat exchanger differing from Fig. 2 with regard to the arrangement of feed and discharge pipes and the matrix, which in Fig. 2a is in "triple-cross-counterflow" construction, representing another application of the invention, namely a three-fold cross-countercurrent construction with an approximately diagonally facing arrangement of the feed and discharge pipes 7, 7' formed between and over the plates 1, 2. The resulting duct matrix is divided into three pipe-area sections or panels Fd1, Fd2, Fd3 flowed through in opposite directions and connected at the inlet side F to the feed pipe 7 via respective rings 9 and at the outlet side F' to the discharge pipe 7' via respective rings 9. By way of example in Fig. 2a, in contrast to the arrangement in Figs. 1 and 2, the inlet into the feed pipe 7 is at the top and the outlet of the discharge pipe 7' is to be understood as at the bottom. In other

respects the functions and modes of operation of Fig. 2a correspond to the reference-sign nomenclature already used in Fig. 2.

Fig. 3 shows how the distributor pipes 7, 7' and the sets of plates 1, 2 are assembled. Each feed pipe is made of a combination of metal spacer rings 9 and rings 8 made of a sealing material, e.g. rubber. The plates 1, 2 are formed simultaneously with the feed pipe 7 and practically identical discharge pipe 7'. In accordance with the invention the plates are basically braced together against the rings 8, 9 and clamped in the longitudinal direction of the pipes. In Figs. 3, 4 and 5 there is a combination of rings 8 made of elastomeric material and metal spacer rings 9, forming a tower which essentially constitutes the backbone of the pipes 7,7' and takes the compressive force.

Each pair of plates 1, 2 which, as mentioned, is welded together at the edges U, U', contains a spacer ring 9, connected through apertures 10 to the group of ducts 4 in the matrix. There is of course a corresponding spacer ring for the other pipe 7'. The plates have flat supporting or abutting portions 11, 12 resting against one another in the region of the edges of the plates. Away from these abutting portions the pairs of plates 1, 2 form cavities Z between widened shaped portions 13, 14 which are complementary about the plane of the abutment, perpendicular to the pipe axis. In the cavities, the rings 8 provide a seal, clamped on the side of the plates, against the other ducts 3 and also against the exterior. The widened plate portions 13, 14 contain openings 5 in the feed pipe 7, surrounded by the respective rings 8, 9. A spot weld or, optionally, a soldered connection can be provided along the supporting portions 11, 12.

Each welded pair of plates 1, 2 constitutes a module which can be replaced or added in if necessary.

The metal spacer rings 9 have openings for supplying the heat-absorbing fluid (cooling water); these apertures 10, 10' in the spacer rings 9 (Figs. 4, 5) are provided by recesses which are open towards one axial end of the ring, and by matching surfaces of the respective shaped portion 13 adjacent the open sides of the recesses. The resulting apertures 10 in Fig. 4 have a generally arch-shaped cross-section which on one side is partly approximately semicircular and then continues outwards in an approximately rectangular shape. Fig. 5 is a view derivable from A-A in Fig. 3, but illustrating a second embodiment of openings formed on one side between the spacer rings and an adjacent plate; here the apertures 10' have a square cross-section. The annular webs left between the apertures 10, 10' end at an obtuse joint angle relative to the extension of the portion 13.

With such a construction the plates 1, 2 can be made of relatively thin sheet metal (approx. < 0.5mm) and the required clamping forces need only be relatively small, to produce a mechanically stable plate construction sealed in an optimum manner at the necessary places (cooling water and hot air). Any displacement of the plates, the result of temperature or temperature change or mechanical stresses, can be corrected in very simple manner by slight re-adjustment; this also applies to the other examples (Figs. 6 to 11).

As shown more particularly in connection with Figs. 3, 4 and 5, according to another feature the respective axial height H of an aperture 10 or 10' is < 2/3 of the maximum wall height D of the spacer ring 9, and the circumferential width B of the aperture 10 is < 5 mm. In connection therewith, the limiting flow area for one recess can preferably be of the order of up to 1/20 of the narrowest flow cross-section of an

opening 5 of a feed or discharge pipe 7 or 7'.

Fig. 6 shows a feed-pipe construction which differs from Fig. 3 in that the metal spacer rings forming the respective openings have a U-shaped cross-section which is open on one side opposite a plate; in the radial plane the U-section of the respective spacer rings 15, which are disposed inside a pair of plates 1, 2, which can again be welded at the edge, is open at one end in the longitudinal direction of the feed duct 7. The spacer rings 15 have transverse apertures 16 defined by projecting supporting legs, which connect the feed pipe 7 on the respective spacer ring 15 to the one group of ducts 4 in the matrix. The aforementioned "projecting" ends of the supporting legs are permanently secured to the respective shaped plate portion 13. These spacer rings 15 reduce the weight considerably, while maintaining a relatively high dimensional stability.

Fig. 7 shows a variant of the plate matrix and the feed-pipe construction which differs from Fig. 3 in that rings clamped between each two plates in neighbouring pairs are formed of a combination of profiled metal spacer rings and O-ring seals. The rings 8 of Figs. 3 to 5, made of rubber or an elastomeric material, are here replaced by rings 16 each consisting of a combination of a spacer and sealing ring 16' which contains a sealing gasket 16'', e.g. of rubber or Teflon. The gaskets are set or disposed in end-face peripheral grooves, and locally squeezed so as to bear in sealing-tight manner on the respective co-operating surfaces of the shaped plate portions 13, 14. At the same time, with a surface contour P on the inner periphery of the ring so as to increase the heat transfer, the ring combination 16', 16'' can be highly effectively cooled, i.e. by heat exchange between the cooling water supplied through the

feed pipe 7 and the hot compressor air from the supercharger (ducts 3 in Z).

Figs. 8, 9 and 10 show a variant viewed as in Figs. 3, 6 and 7 and differing from these embodiments more particularly in that all the rings have spacing and sealing properties and, between their respective ends facing one another in the axial direction of the pipe, have recesses for receiving ducts for the heat-absorbing fluid (cooling water) incorporated in pairs in the plates. Fig. 9 shows cylindrical ducts incorporated in plate pairs for anchoring between facing, approximately semicircular, recesses in adjacent ring end-faces; and Fig. 10 shows duct cross-sections, hexagonal by way of example in the present case, incorporated in plate pairs for anchoring between approximately trapezoidal facing recesses in adjacent annular end faces. In this embodiment all the rings 17 between the plates 1, 2 also serve as sealing elements which transmit bearing forces and are made e.g. of hard rubber. A pair of plates 1, 2 forming each duct 4 or (in Fig. 10) 4' is anchored between axial end faces of the rings 17. The complementary portions 13, 14 formed by shaping the plates 1, 2 extend from the facing flattened supporting portions 11, 12 and are disposed partly, in the region of the openings 5, directly on top of one another, as at the exterior face of the heat exchanger. The rings 17 partly enclose ducts 4 (Fig. 9) or 4' (Fig. 10) between correspondingly contoured plate shapes at complementary recesses 18 (Fig. 9) or 19 (Fig. 10) formed between facing ends, the ducts having a circular or cylindrical cross-section in Fig. 9 and a polygonal, e.g. hexagonal cross-section in Fig. 10. In this embodiment there is only one ring per pair of plates for each pipe 7, 7'.

Advantageously in all the previously-discussed embodiments, the portions of a pair of plates 1, 2

extending from the locally flattened supporting portions 11, 12 to one end or in the corners towards strip-like connecting flanges U, U' likewise enclose outer duct structures 20 in the matrix; these can likewise be connected e.g. to the feed pipe 7 via openings in or on the rings.

Fig. 11 shows a partial section of the matrix of the heat exchanger, in which the respective spacer ring is disposed in an annular bulge or pocket formed between the complementary shaped plate portions with openings. In the embodiment in Fig. 11, respective pairs of plates 1, 2, relative to the superposed arrangement of the respective openings 5 of the feed pipe 7, enclose annular pockets T each containing spaced-apart rings 30. The rings are connected to an initially radially extending group of ducts 4 in the matrix, incorporated into the plates, via openings 21 at opposite peripheral regions of the pocket. Additional rings 22, comparable with the rings 16' in Fig. 7, are provided for the other ducts 3 in a locally spaced-apart construction of the cavities Z and, with interposition of additional sealing rings 16'' or cords, abut annular surfaces formed by locally ring- or disc-shaped bulging portions 13, 14 of the plates 1, 2; the openings 5 in one set of plates (e.g. 2) end in respective annular flanges 23 which engage in and centre the rings 22. The means for centring the rings 30, marked 24 in Fig. 11, can be embossed beads, knobs or the like.

In the previously-mentioned examples, i.e. in Figs. 3 to 9, the rings 8 or 16' or 17' can likewise be anchored in annular pockets formed by the shaped plate portions 13 and 14.

In Fig. 12, a releasable clamping and sealing connection 25 in the form of a releasable rubber clamping seal on the outer edge can be provided instead

of a locally sealed soldered or welded connection along the outer edges U, U' of the pair of plates 1, 2. The outer edges U, U' constituting the matching seat and support surfaces can have rounded projecting tongues 26, 27 which engage round a part of the periphery of a rubber or rubber-like cord 28. A clamping tube 29 slotted on one side surrounds the cord 28 and tongues 26, 27 and clamps the outer edges U, U' as if in tongs.

The invention can also be applied to a plate heat exchanger comprising spaced-apart parallel adjacent feed pipes and/or discharge pipes, preferably in both corner regions of the plate matrix. For example, locally separated ducts 4 in the respective pipe areas can be flowed through in opposite directions and their inlet ends can be connected to a feed pipe and their outlet ends to a discharge pipe. With the invention, since a column of rings is provided to make up each of the feed and discharge pipes these columns can provide the structural stability of the heat exchanger, allowing the plates 6 to be made of thin sheet material. The rings are preferably circular but other sections (transverse to the pipe axis) are possible.

CLAIMS

1. A heat exchanger comprising a matrix of stacked superposed plates (1, 2) which enclose separate ducts (3; 4) for two fluids involved in heat exchange and have complementary shaped portions (13, 14) with openings (5) for the formation of feed pipes and discharge pipes (7, 7') respectively connected to one group of ducts (4),

in which the feed pipes and discharge pipes (7, 7') are each further made up of rings (8, 9) arranged along the axis of the respective pipe and clamped in a sealing-tight manner between the shaped portions (13, 14), these rings in their various axially spaced planes forming a fluid connection with one group of ducts (4) and/or a fluid barrier against the other group of ducts (3) in the matrix.

2. A heat exchanger according to claim 1, in which each shell-like pair of plates (1, 2) forms one set of the first group of ducts (4) of the matrix between complementary formed portions and is welded or soldered together in a sealing-tight manner along external facing edges (U, U').

3. A heat exchanger according to claim 1 or 2, in which at least some of the rings (8, 17, 22) are made at least partly of rubber or an elastomeric material so as to block the fluid connection between a feed or discharge pipe (7, 7') and the second group of ducts (3), these ducts being contained in cavities (Z) between the shaped plate portions (13, 14).

4. A heat exchanger according to one or more of claims 1 to 3, in which the rings (8, 9) are disposed between the plates (1, 2) respectively to surround the openings (5) contained in the shaped plate portions (13, 14) of a feed or discharge pipe (7, 7').

5. A heat exchanger according to one or more of

claims 1 to 4, in which some of the rings are made at least partly of metal and these metal rings (9, 15) are anchored in a respective pair of plates (1, 2) enclosing the first group of ducts (4) in the matrix, and are connected via openings or apertures (10, 10', 16) to the first group of ducts (4).

6. A heat exchanger according to claim 5, in which the openings or apertures (10, 10', 16) are formed between recesses which are open to one axial end of the ring (9, 15) and flat matching surfaces of the corresponding shaped plate portion (13), webs remaining between the recesses resting on the plate portion (13) and subtending an obtuse joint angle.

7. A heat exchanger according to claim 5 or 6, in which the respective axial height (H) of an aperture (10, 10') is < 2/3 of the maximum wall height (D) of the respective ring (9) and the width of the aperture (B) is chosen at < 5 mm, the flow area provided by each aperture (10, 10') or duct (4) (Fig. 9) being designed to be not more than 1/20 of the narrowest flow cross-section of the feed or discharge pipe (7, 7').

8. A heat exchanger according to claim 5, in which the walls of the metal rings (15) have a U-shaped cross-section, taken in a radial plane, open at one side in the longitudinal direction of a feed or discharge pipe (7, 7'), the transverse apertures (16) defined by free supporting legs being connected to the first group of ducts (4).

9. A heat exchanger according to claim 3, in which the said ring made at least partly of rubber includes a rubber ring having its outer surface enclosed by a metal ring.

10. A heat exchanger according to any of claims 1 to 7, in which the feed pipe (7) is flowed through by a heat-absorbing cooling fluid, the rings (16') blocking the feed pipe (7) against hot fluid in the second ducts

(3) being metallic and provided on their inner periphery with a surface contour (P) which increases the heat transfer, and resting on matching surfaces of neighbouring plates (2, 1) via sealing rings (16'') or cords inserted into peripheral grooves.

11. A heat exchanger according to any of claims 1 to 4, in which the rings (17), in the form of successive sealing and supporting force-transmitting elements in the axial direction of the pipe, make up a feed or discharge pipe (7, 7') and surround correspondingly contoured shapes on a pair of plates (1, 2) by virtue of complementary recesses (18, 19) on opposite ends of the rings, these shapes together forming the first group of ducts (4, 4').

12. A heat exchanger according to one or more of claims 1 to 11, in which the pairs of plates (1, 2) at end regions of the matrix, starting from supporting portions (11, 12) forming opposite contact surfaces, afford the respective complementary-shaped plate portions (13, 14) for the rings, the pairs of plates (1, 2) between the supporting portions (11, 12) enclosing respective complementary-shaped duct structures (20) along the edges of the heat exchanger, adapted to be supplied with fluid via the rings (9, 15).

13. A heat exchanger according to claim 12, in which the pairs of plates (1, 2) are spot-welded or soldered at the supporting portions (11, 12).

14. A heat exchanger according to claim 12, in which the pairs of plates (1, 2) interlock in a sealing and centring manner at the supporting portions (11, 12).

15. A heat exchanger according to one or more of claims 1 to 14, in which the spacing and/or sealing rings are centred by webs, knobs, beads, projections or the like on the respective seat surfaces of the shaped

plate portions (13, 14).

16. A heat exchanger according to one or more claims 1 to 15, in which one group of rings (30) are anchored in respective annular pockets (T) formed between complementary bulging portions of a pair of plates (1, 2).

17. A heat exchanger according to one or more of claims 1 to 16, in which the openings (5) in a pair of plates (1, 2), on at least one shaped side of the plate, merge into axial annular flanges (23) which engage into a respective spacing and/or sealing ring (22).

18. A heat exchanger according to claim 1, in which the pairs of plates (1, 2) are releasably connected by a rubber clamping seal (25) along facing outer edges (U, U').

19. A heat exchanger substantially as described herein with reference to any of the embodiments shown in the accompanying drawings.

Patents Act 1977 **Examiner's report to t[illegible]mptroller under Section 17** **(T[illegible] Search report)**	Application number [illegible]9404659.6
Relevant Technical Fields (i) UK Cl (Ed.M) F4S (S4G, S4JY, S4JX) (ii) Int Cl (Ed.K) F28F (3/00, 3/08, 3/10, 7/00, 7/02, 9/02)	Search Examiner T M JAMES Date of completion of Search 9 MAY 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1-19

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X	GB 2034872	(GARRETT CORP) See itme 52 in Figure 5	1 at least
X	GB 1558575	(ALFA LAVAL) See Figures 1 and 2	1 at least
X	GB 1199067	(ROSENBLAND) See the Figures	1 at least
X	EP 0021161 A1	(HOECHST AKTIENGESELLSCHAFT)	1 at least
X	EP 0008268 A1	(CEA) See Figure 2	1 at least

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